Proceedings of the Seventh International Coral Reef Symposium, Guam, 1992, Vol. 2

A Preliminary Assessment of the Marine Aquarium Export Trade in Puerto Rico

YVONNE SADOVY

Fisheries Research Laboratory, Department of Natural Resources, P O Box 3665, Mayagüez, Puerto Rico 00681

Abstract. Puerto Rico's export trade in marine aquarium organisms was characterized through a series of informal interviews and inspection of export shipment species lists. A total of 106 species, or species groups, of fish and invertebrates was estimated as exported in 1990–1991, totalling between 160,000 and 200,000 organisms for 1991. Seventy percent of this volume was composed of six species or species groups. Six export businesses employ up to 100 full- and part-time personnel between them. The industry is not regulated. An urgent need for monitoring and regulating this growing activity is recognized and recommendations are developed for managing the industry. Particular concern is expressed over methods employed in the collection, handling and shipping of fishes and invertebrates, the lack of comprehensive inspection of export shipments, and the virtual absence of enforcement of existing laws and regulations.

Introduction

There has been concern in Puerto Rico over the last 2–3 years regarding the growing export trade in live marine organisms marketed for the aquarium industry. Both those active within the trade and those familiar with Puerto Rico's marine resources believe that intensive collection could impact exploited populations and associated habitat. Possible reasons for local growth in this trade are the excellent air transport facilities, increasing restrictions on Florida-based collectors, and a growing demand for marine aquarium organisms in general.

Export of organisms for the aquarium trade from Puerto Rico began in the early 1970's, at which time Lubbock and Polunin (1975) found exporters in Puerto Rico listing 49 species available for export. The aquarium fish trade is not specifically managed, although the harvest of certain marine species, or sizes thereof, and the use of poisons, are regulated in US Federal and/or Commonwealth of Puerto Rico waters. The taking of coral and "live rock" (a broad term used to describe rocky substrate colonized by marine organisms, Wheaton 1989) is prohibited in Commonwealth waters. Neither collectors nor exporters are required to have licences.

There is no information regarding this trade in Puerto Rico. Such information is essential for issues to be addressed concerning management. The purpose of this study was 2-fold:

1. to provide a first assessment of the nature and extent of the trade in Puerto Rico by documenting the number of people involved islandwide, by determining the species exploited and by identifying the principal areas and methods of collection;
2. to identify monitoring and data needs to enable development of a management policy for the industry in Puerto Rico, and to produce preliminary management recommendations.

Materials and Methods

Information was obtained from standardized informal interviews with knowledgeable contacts both within and outside the aquarium trade in Puerto Rico and in Florida, as well as with officials of the Florida and Puerto Rico Departments of Natural Resources (PRDNR). Information contained in shipping lists was summarized by species, or species group, and the numbers of boxes of organisms imported and exported per month, for 1990–1991, were determined. These lists are provided at the

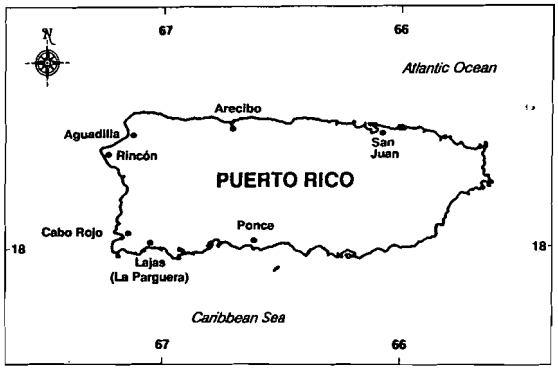

Fig. 1. Principle areas of collection identified in the text. Offshore islands are not shown. Isla de Desecheo lies 20 km west of Rincón. Isla de Caja de Muertos lies 9 km south of Ponce (Scale: 8.5 mm = 10 km)

time of export to PRDNR personnel at the principal island airport in San Juan. Company trade lists were also examined to establish which species are advertised as available from Puerto Rico.

Results

Collectors/Exporters

Most collectors are exporters, although some collectors also sell their catch to an exporting middleman, and, occasionally to island pet shops. Three of the six identified export businesses have been active in the trade for a number of years. One recently established business is reportedly initiating a breeding program for Indo-West Pacific anemonefish (clownfish). Combined, the businesses depend on about 40 regular collectors working full- or part-time, with additional individuals (including schoolchildren) collecting casually (i.e. weekend, school holiday). Less than 100 people are involved in all phases of the aquarium trade, from collectors and their assistants, to biologists, packers and shippers. Most exporters depend for the majority of their income on the export trade.

Methods Used for the Harvest of Marine Organisms

Collectors/exporters own their own boats, diving and collecting gear. Boats are about 7 m in length. Collecting trips may be made 7 days a week if weather permits and demand is high, otherwise collecting trips occur 3–4 days weekly. Demand tends to be highest in the winter and lowest in the summer months. SCUBA is used down to 20 m but occasionally to 40 m for certain species. Mask and snorkel are commonly used in shallow-water areas. Fish are generally captured at lengths of between 3.5–13 cm, depending on the species.

Collection is by net (barrier, gill, drop or cast, and hand or dip nets), fish trap (6.35 mm–22.70 mm mesh), chemicals such as 'quinaldine', and slurp gun (not common). Cast nets are small circular nets with weights attached along the outer edge, and hand or dip nets are generally comprised of 3.12 mm monofilament mesh and may incorporate plastic panels. There are also reports that bleach, formalin and gasoline are used on occasion. Quinaldine (2-methyl-quinoline) is mixed with isopropyl, or ethyl, alcohol or acetone, diluted with seawater and dispensed from bags, small plastic bottles or pressure sprayers. Concern was expressed that the collection of certain organisms, such as brittlestars, flame scallops, and some anemones and tube worms, often necessitates displacement or removal of rock or live coral substrate.

Areas Collected

Collection areas are principally located in western Puerto Rico (La Parguera, Cabo Rojo, Rincón, Aguadilla, Arecibo, Desecheo Island 20 km west of Rincón) and at specific locations along the south coast (e.g. Isla de Caja de Muertos south of Ponce) (Fig. 1). Several heavily collected sites are popular tourist areas or are commercially fished. Collectors report that they rotate their use of specific collection areas to avoid overharvesting.

Species Collected

Export information was obtained from a total of 92 (species composition data) and 81 (number of boxes exported data) shipping lists, respectively, and 5 different shippers. The shipping lists utilized do not constitute a random subset of all island exporters as some, not necessarily the biggest, are more frequently represented than others.

Species composition, taken from species itemized in shipping lists, or as advertised in company trade lists as available, is shown in Table 1. A total of 104 fish species and 49 (plus a few unidentified 'miscellaneous') invertebrate species, or species groups, appeared on trade lists. Of these, 82 fish species and 24 (+ miscellaneous) invertebrates were noted as exported. Six species, or families, made up 70% of the total fish export: *Gramma loreto*; *Opistognathus aurifrons*; *Holacanthus tricolor*; *Pomacanthus paru*; *Balistes vetula*, and assorted blennies. Principal fish families exported were Grammidae (Grammatidae)—basslets, Opistog-

Table 1. Fish and invertebrate species, or species groups/families, exported from Puerto Rico, or indicated on company trade lists as available for export, according to trade and shipping lists for 1990/1. Numbers exported are individual organisms.

Species/Species Group	Common Names	Number Exported
FISHES:		
Unspecified elasmobranchs	SHARKS, SKATES, RAYS	
ANGUILLIFORMES		
Gymnothorax miliaris	GOLDENTAIL MORAY	44
Gymnothorax funebris	GREEN MORAY	
Myrichthys oculatus	GOLDSPOTTED SNAKE EEL	4
Echidna catenata	CHAIN MORAY	
Unspecified muraenids	MORAY "EELS"	8
AULOPIFORMES		
Synodus intermedius	LIZARDFISH	1
BERYCIFORMES		
Plectrypops retrospinis	CARDINAL SOLDIER	183
Holocentrus ascensionis	LONGJAW SQUIRRELFISH	5
Myripristis jacobus	BLACKBAR SOLDIERFISH	242
Unspecified holocentrids	SQUIRRELFISH	3
PERCIFORMES		
Apogon maculatus	FLAME/FISH/CARDINAL	98
Astrapogon stellatus	CONCHFISH	1
Priacanthus arenatus	BIGEYE	24
Priacanthus cruentatus	GLASSEYE	26
Chromis cyanea	BLUE CHROMIS	439
Chromis insolatus	SUNSHINE DAMSELFISH	20
Abudefduf saxatilis	SERGEANT MAJOR	12
Stegastes partitus	BICOLOR DAMSELFISH	
Stegastes leucostictus	BEAUGREGORY	49
Stegastes planifrons	YELLOW DAMSELFISH	20
Stegastes dorsopunicans	DUSKY DAMSELFISH	
Microspathodon chrysurus	YELLOWTAIL/JEWEL DAMSEL	299
Unspecified pomacentrids	DAMSELFISH	8
Thalassoma bifasciatum	BLUEHEAD WRASSE	612
Clepticus parrae	CREOLE WRASSE	43
Halichoeres cyanocephalus	LIGHTNING WRASSE	20
Halichoeres radiatus	PUDDING WIFE	587
Halichoeres maculipinna	CLOWN WRASSE	34
Halichoeres garnoti	YELLOWHEAD/NEON WRASSE	122
Xyrichtys splendens	RAZORFISH/GREEN WRASSE	26
Bodianus rufus	SPANISH HOGFISH	462
Unspecified labrids	WRASSES	
Sparisoma chrysopterum	REDTAIL PARROTFISH	
Scarus taeniopterus	PRINCESS PARROTFISH	
Unspecified scarids	PARROTFISH	20
Centropyge argi	PYGMY ANGELFISH	345
Pomacanthus paru	FRENCH ANGELFISH	882
Pomacanthus arcuatus	GRAY ANGELFISH	7
Holacanthus ciliaris	QUEEN ANGELFISH	114
Holacanthus tricolor	ROCK BEAUTY	1552
Unspecified pomacanthids	ANGELFISH	7
Chaetodon capistratus	4-EYE BUTTERFLYFISH	133
Chaetodon ocellatus	SPOTFIN BUTTERFLYFISH	
Chaetodon striatus	BANDED BUTTERFLYFISH	338
Chaetodon aculeatus	LONGSNOUT/NOSE BUTTERFLY	111
Unspecified chaetodontids	BUTTERFLYFISH	98
Gramma loreto	ROYAL GRAMMA	11124
Serranus tabacarius	TOBACCO FISH	57
Serranus tigrinus	HARLEQUIN BASS	76
Serranus annularis	ORANGEBACK BASS	1
Serranus baldwini	LANTERN BASS	13
Serranus tortugarum	CHALK BASS	54
Unspecified serranids	BASSES	14
Liopropoma rubre	SWISSGUARD BASSLET	6

Table 1. (*Continued*).

Species/Species Group	Common Names	Number Exported
Hypoplectrus nigricans	BLACK HAMLET	
Hypoplectrus indigo	INDIGO HAMLET	
Hypoplectrus unicolor	BUTTER HAMLET	
Hypoplectrus puella	BARRED HAMLET	
Hypoplectrus guttavarius	SHY HAMLET	1
Hypoplectrus gummigutta	GOLDEN HAMLET	
Hypoplectrus aberrans	YELLOWBELLIED HAMLET	
Unspecified serranids	HAMLETS	12
Paranthias furcifer	CREOLE FISH/ANTHIAS	135
Epinephelus fulvus	CONEY/GOLD CONEY	53
Epinephelus guttatus	RED HIND	12
Unspecified serranids	GROUPER	47
Rypticus saponaceus	SOAPFISH	1
Equetus punctatus	SPOTTED DRUM	21
Equetus lanceolatus	JACKKNIFE FISH	22
Pareques acuminatus	CUBBYU/HIGH-HAT	205
Chaetodipterus faber	SPADEFISH	6
Amblycirrhitus pinos	REDSPOTTED HAWKFISH	31
Anisotremus virginicus	PORKFISH	17
Ophioblennius atlanticus	REDLIP BLENNY	451
Unspecified blenniids	BLENNIES	948
Gobiosoma spp.	NEON GOBY	
Quisquilius hipoliti	RUSTY GOBY	
Unspecified gobiids	GOBIES	
Opistognathus aurifrons	YELLOWHEAD JAWFISH	2631
Opistognathus whitehurstii	DUSKY JAWFISH	126
Unspecified mullids	GOATFISH	9
Acanthurus coeruleus	BLUE/YELLOW TANG	367
Acanthurus chirurgus	SURGEON TANG/DOCTORFISH	50
TETRAODONTIFORMES		
Balistes vetula	QUEEN TRIGGERFISH	920
Xanthichthys ringens	SARGASSUM/REDTAIL TRIGGERFISH	74
Canthidermes sufflamen	OCEAN TRIGGERFISH	1
Melichthys niger	BLACK TRIGGERFISH	76
Aluterus scriptus	SCRAWLED FILEFISH	
Cantherhines macrocerus	WHITESPOTTED FILEFISH	22
Unspecified monacanthids	FILEFISH	
Lactophrys, Acanthostracion	TRUNKFISH, COWFISH	
Canthigaster rostrata	SHARPNOSE PUFFER	36
Diodon hystrix	PORCUPINEFISH	2
LOPHIIFORMES		
Antennarius spp.	FROGFISH	70
Ogcocephalus spp.	BATFISH	6
SYGNATHIFORMES		
Unspecified aulostomids	TRUMPETFISH	60
Hippocampus spp.	SEA HORSE	24
Unspecified sygnathids	PIPEFISH	
DACTYLOPTERIFORMES		
Dactylopterus volitans		
SCORPAENIFORMES	FLYING GURNARD/SEA ROBIN	437
Unspecified scorpaenids	SCORPIONFISH (STONEFISH)	
PLEURONECTIFORMES		
Bothus lunatus	PEACOCK FLOUNDER	
	FLOUNDER	23
Symphurus arawak	CARIBBEAN TONGUEFISH	

Table 1. (*Continued*).

Species/Species Group	Common Names	Number Exported
INVERTEBRATES:		
Haliclona spp.	ORANGE TREE SPONGE	45
	RED SPONGE	146
	ELEPHANT EAR SPONGE	50
	GORGONIANS/SEA FANS	
Tubastrea aurea	ORANGE POLYP (CORAL)	
Condylactis	CLUSTER ANEMONE/PINKTIP 382	
Bartolomea annulata	CURLIQUE ANEMONE	150
	COLONY ANEMONE	45
Stoichactis helianthus	CARPET ANEMONE	105
Ricordea florida	GREEN ANEMONE	
Phymanthus crucifer	ROCK ANEMONE	10
Heteractis lucida	STINGING ANEMONE	
Aiptasia tagetes	ANEMONE	
Zoanthus spp.	ORANGE TUNICATE(?)/SEA MAT	
Sabellastarte magnifica	SOLO FEATHER DUSTER	75
Sabellastarte spp.	COLONIAL/CLUSTER DUSTER	61
Spirobranchus giganteus	CHRISTMAS TREE WORM	
Panulirus argus	SPINY LOBSTER	
Periclimenes spp.	ANEMONE SHRIMP	
Stenopus hispidus	RED-BANDED CORAL SHRIMP	102
Stenopus scutellatus	GOLD SHRIMP	2
Alpheus armatus	PISTOL SHRIMP	162
Lysmata spp.	PEPPERMINT SHRIMP/SCARLET/LADY	15
Thor amboinensis	BUMBLEBEE SHRIMP	
Pseudosquilla	MANTIS SHRIMP	
Unspecified hermit crabs		10
Paguristes cadenati	RED LEG HERMIT	
Mithrax sculptus	GREEN/EMERALD CRAB	20
Percnon gibbesi	SALLYLIGHT/URCHIN CRAB	
	DECORATOR/SPONGE CRAB	
Stenorhynchus seticornis	ARROW CRAB	78
Mithrax cinctimanus	ANEMONE CRAB	
Cyphoma gibbosum	FLAMINGO TONGUE	
Lima scabra	FLAME SCALLOP	280
	SPINY OYSTER	
Charonia variegata	TRITON	
Oliva reticularis	MEASLE COWRIE/OLIVE SHELL	
Tridachia crispata	NUDIBRANCH	
	OCTOPUS	
Astropecten	SAND STAR	76
Oreaster reticulatus	RED BAHAMA/WEST INDIES STARFISH	83
Subclass OPHIUROIDEA	BRITTLESTAR	180
Ophioderma	RED/SERPENT/BURGUNDY	
	BRITTLESTAR	481
Astrophyton	BASKET STAR CRINOID	
Diadema antillarum	LONG SPINE URCHIN	
Lytechinus spp.	PIN CUSHION URCHIN	
Eucidaris tribuloides	PENCIL URCHIN	103
Echinometra spp.	PURPLE/ROCK URCHIN	
MISCELLANEOUS INVERTEBRATES		135

nathidae—jawfish, Pomacanthidae—angelfish, Chaetodontidae—butterflyfish, Pomacentridae—damselfish, Holocentridae—squirrelfish, Blenniidae—blennies, Labridae—wrasses, and Balistidae—triggerfish. The Serranidae—grouper, hamlets and basses, provided the greatest species diversity of any one family. The queen triggerfish, *Balistes vennt*ula, and trunkfishes, are important components of the island's commercial fishery, as are the groupers *Epinephelus guttatus* and *E. fulvus* (Matos and Sadovy 1991). As the condition of the commercial fishery of Puerto Rico deteriorates, the juveniles of several species valued by the aquarium trade are increasingly being marketed as adults by commer-

cial fishermen (e.g. wrasses, parrotfish, squirrelfish and angelfish), increasing the potential for user conflict. Fishes are most commonly exported at sizes ranging from 3.5—13 cm.

A wide variety of invertebrates was exported, in particular anemones, shrimps, crabs, flame scallops, and various echinoderms, e.g. brittlestars, starfish and urchins. I believe that the relative numbers of invertebrates are grossly underrepresented in this report, however. For example I received information indicating that many hundreds of anemones and brittlestars may be removed in a single day from La Parguera. There were difficulties in identifying a number of organisms to species; common or trade names were used which are not species-specific. Although the taking of coral and live rock is illegal, both are reportedly commercially harvested.

Handling and Shipping

Animals are taken to holding facilities, usually adjacent to collector/exporter residences, and generally retained for a few days prior to packing and export. Facilities vary from, most commonly, a simple operation consisting of plastic "paddling pools" fed by a simple flow-through water system, to a series of glass and concrete tanks, under-gravel and ultra-violet filters, and protein skimmers.

For shipping, animals are packed in single or double plastic bags. These are filled with oxygen by some exporters and placed in boxes for shipping. Boxes vary in dimension from 30 × 43 × 43 cm to 53 × 53 × 53 cm and may be lined with insulating material, depending on shipper, destination and season. Most organisms are currently shipped to the US mainland, the balance to Canada, and to Europe, particularly to the UK and Germany. Some export also occurs out of secondary island airports and reportedly, on occasion, through the postal system. Export shipments are sporadically inspected by PRDNR personnel at San Juan airport, and require inspection by the US Division of Fish and Wildlife if destined outside of US territory.

Estimates of mortality from the time of capture to the time of export varied within a range of about 10% to 20%, depending on capture, handling and shipping methods, the level of skill of collectors and conditions of holding facilities. This estimate of mortality is high compared to mortality rates reported for net-caught fish in Hawaii (van Poollen and Obara 1984) and relative to the most commonly cited level in the industry of 10% (Wood 1985). Some fish importers consider mortality rates of more than a few percent to be unacceptable (Richard Sankey pers. comm.).

Estimated Export/Import Volume (1990–1991)

From shipping lists, it was determined that an average shipment of fish and invertebrates comprises 12 boxes (range 2–29) and that each box on average contains 31 organisms (range 7–100, depending on the species involved and their size). It was estimated from interviews with exporters that an average of at least 9 shipments a week leave San Juan: individual exporters vary in the number of shipments from 1–3 per week. This provides a monthly estimate of 432 boxes exported per month, and 5184 boxes per year, containing an annual total of approximately 160,000 organisms through San Juan airport alone, with values ranging between US$ 1–5 per organism (not including live rock). These figures provide no indication of additional organisms lost through mortality between capture and shipment, sold to island pet shops, or exported from other locations.

The number of boxes exported appearing in PRDNR records (2448 for 10 months) (Table 2) is clearly a gross underestimate of true exports. This conclusion is supported, in part, by reports of zero boxes in June, July and August, 1991, during which months export shipments were made according to interviews with collectors/exporters. Furthermore, Department figures did not include shipments out of secondary airports. Imports of marine fishes are probably destined for home aquaria in Puerto Rico, and, more recently, for breeding programs. There are no regulations which specifically address the importation of exotic marine species: introduced marine exotics have flourished in Hawaiian waters (Oda and Parrish 1981; Randall 1987).

Discussion

Many of the findings and concerns expressed in this study reflect those of reports on the trade in aquarium organisms elsewhere (e.g. Conroy 1975; Dawson-Shepherd 1977; de Kruijf 1978; Albaladejo and Corpuz 1981; Wood 1985; Whitehead et al. 1986; Edwards 1988; Barratt and Medley 1990). It is essential that the expanding export trade in Puerto Rico be monitored on a regular basis and managed to ensure sustainable resource use for maximum possible conservation and economic benefits. Currently, there are few regulations which relate to this trade and almost no enforcement of those that do.

The aim of managing any resource is to ensure sustainable use in a manner which does not damage

Table 2. Numbers of boxes of marine fish and invertebrate species exported from and imported to Puerto Rico through the Luis Muñoz Marín airport, San Juan, by month for 1990 and 1991 (Source: Puerto Rico Department of Natural Resources)

	1990		1991	
MONTH	EXPORT	IMPORT	EXPORT	IMPORT
JANUARY	11	359	218	172
FEBRUARY	36	453	218	145
MARCH	0	0	98	192
APRIL	0	470	243	108
MAY	86	701	1,291	213
JUNE	332	637	0	154
JULY	239	726	0	149
AUGUST	146	0	0	87
SEPTEMBER	125	153	145	N/A*
OCTOBER	177	177	235	N/A
NOVEMBER	135	124	N/A	N/A
DECEMBER	114	167	N/A	N/A
TOTALS	1,401	3,967	2,448	1,220

* N/A—information not available

the environment, and minimizes user conflict. In the case of the aquarium organism trade, it is also important to take into consideration measures aimed at maximizing the survivorship of harvested fish and invertebrates and to restrict or prohibit the marketing of species unsuitable for captivity.

There is no information regarding abundances or levels of sustainable yield of harvested aquarium trade species in Puerto Rico, other than for the red hind, *Epinephelus guttatus* which is growth overfished (Sadovy and Figuerola 1992). Scientific evidence regarding the effects of heavy fishing pressure on aquarium species is mixed and is likely to be both species- and location-dependent. For example, areas heavily collected in the Bahamas using rotenone required between 4–9 months to re-establish pre-collection population equilibrium (Smith 1973). Pfeffer and Tribble (1985) concluded that heavy collecting may have locally depleted populations of reef fish, which, combined with hurricane damage, led to the collapse of the industry in Hawaii. In Curaçao, de Kruijf (1978) determined that several commonly harvested angelfishes required collecting limits. Florida has recently imposed a number of restrictions, including quotas, size limits, closed seasons and the complete phasing out of "live rock" harvest, because of concerns over overexploitation of several species. On the other hand, a 2.5 year study in Hawaii indicated that more heavily collected areas did not show greater reductions when compared to non-collected areas (Taylor and Nolan 1978). Randall (1987) argued that larval recruitment will be sufficient to replenish diminished populations, assuming, of course, that populations are not recruitment-limited. He did caution, however, that rare species were potentially vulnerable.

Locally exploited species need to be evaluated for their sustainability, their suitability for the aquarium trade and for the potential impact of their removal on the ecosystem. For example, some butterflyfishes e.g. *Chaetodon capistratus*, *C. striatus* and *C. aculeatus* do not feed well in captivity and consequently experience high mortality, making them unsuitable candidates for the industry (Wood 1992). Removal of certain species may be directly or indirectly detrimental to the reef ecosystem. For example, cleaner fishes, such as juveniles of the wrasses, *Thalassoma bifasciatum* and *Bodianus rufus*, the fairy basslet, *Gramma loreto*, and the angelfish, *Pomacanthus paru*, and 'cleaner' shrimps remove the parasites from a wide range of fish species. Their importance for the health of reef species is unknown. Finally, community imbalance may be caused by excessive harvest of certain species. For example, it has been suggested that population explosions of coral-eating starfish, *Acanthaster planci*, in Sri Lanka, could have been caused by removal of fish that eat its larvae (Wood 1985).

Finally, certain collection methods are unacceptably damaging to reef structure or reef-associated organisms. Certainly, removal or displacement of substrate for access or attached organisms should be regulated or prohibited, as should the use of barrier nets which damage reefs and cause inadvertent mortality (Randall 1987). There is considerable debate regarding the long- and short-term effects of quinaldine on fishes and invertebrates and the reef with which they associate. Nonetheless, since its effects are clearly toxic for certain species of both

fish and invertebrates, or under certain conditions (Gibson 1967; Ireland and Robertson 1974; Colin 1975; Jaap and Wheaton 1975; Hess and Stevely no date; Randall 1987) its use should be regulated, or prohibited (as in Florida and Hawaii, respectively). Indeed, many wholesalers are reluctant or refuse to purchase fish collected with quinaldine because they believe that mortality rates are higher than with net-caught fishes, or that the use of chemicals for collection ought, in general, to be discouraged (Randall 1987, Richard Sankey pers comm).

Recommendations

1. Collectors and exporters of marine organisms for the aquarium trade should be licensed to collect and export marine organisms. The number of licences issued must be commensurate with resource availability and suitability for exploitation. Until resources are evaluated and regulations developed, licensing should be restricted to current participants to avoid untimely expansion of the industry.
2. Licensed collectors/exporters should submit monthly reports on numbers of each species captured, as well as exported, or sold within Puerto Rico, and location(s), method(s) of capture and some measure of catch per unit effort (e.g. trips, hours).
3. Holding facilities and packing materials and techniques should conform to certain specified government standards.
4. Collectors and exporters should be encouraged to participate fully in the development of a management policy for the industry.
5. Inspectors should be trained to recognize marine species of fish and invertebrates to permit comprehensive inspection of export shipments.
6. Heavily collected species must be evaluated to establish current status, to set levels of sustainable yield and to determine their suitability for harvest.
7. The use of damaging collection methods must be regulated or prohibited.

Acknowledgments. Funds for this study were largely provided by the Caribbean Fishery Management Council (United States Department of Commerce/National Oceanographic and Atmospheric Administration). I am grateful to the following for their help: E. Acosta, K. Asoh, J. A. Bohnsack, C. Calzado, G. Cranmore, M. Derr, A. Félix, C. Heberer, H. J. López, L. Kaczmarsky, W. McMillan, J. Rafols, D. Rivera, G. Rogers, R. Sankey and personnel of the PRDNR. Raquel Pérez kindly provided the map.

References

Albaladejo VD, Corpuz VT (1981) A market study of the aquarium fish industry of the Philippines: an assessment of the growth and the mechanics of the trade. Proc 4th Int Coral Reef Symp Vol 1:75–81

Barratt L, Medley P (1990) Managing multi-species ornamental reef fisheries. Prog in UW Sci 15:55–72

Colin PL (1975) The neon gobies. T F H Publ Neptune City, New Jersey, 304 pp

Conroy DA (1975) An evaluation of the present state of world trade in ornamental fish. FAO Fisheries Technical Paper No 146, pp 1–128

Dawson-Shepherd AR (1977) Collected in the Philippines. The Aquarist 7(10):5–14

Edwards AJ (1988) Preliminary report on the aquarium fish export trade of the Republic of Maldives. Centre for Tropical Coastal Management Studies Univ of Newcastle upon Tyne, UK, 22 pp

Gibson RN (1967) The use of the anaesthetic quinaldine in fish ecology. J. Animal Ecology 36(2):295–301

Hess D, Stevely J (No date) The aquarium reef fish collecting industry in Monroe County, Florida. Marine Resource Inventory Monroe County Marine Advisory Program Florida Cooperative Extension Service, pp 1–27

Ireland PJ, Robertson GC (1974) A review of evidence relating to the use and effects of sodium cyanide and other methods commercially employed on coral fish collecting. British Marine Aquarists Association Booklet No 2, pp 1–15

Jaap WC, Wheaton J (1975) Observations on Florida reef corals treated with fish-collecting chemicals. Florida Marine Research Publications No 10, pp 1–17

de Kruijf HAM (1978) Report on the export of fishes and invertebrates for the aquarium trade from Curaçao 1972–1977. STINAPA documentation series No 1, pp 1–24

Lubbock HR, Polunin NVC (1975) Conservation and the tropical marine aquarium trade. Envir Conserv 2(3):229–232

Matos D, Sadovy Y (1991) Puerto Rico Department of Natural Resources/National Marine Fisheries Service annual report for the Interjurisdictional Fisheries Program. June 21st 1991, pp 1–53

Oda DK, Parrish FD (1981) Ecology of commercial snappers and groupers introduced to Hawaiian reefs. Proc 4th Int. Coral Reef Symp, Manila 1:59–67

Pfeffer RA, Tribble GW (1985) Hurricane effects on an aquarium fish fishery in the Hawaiian Islands. Proc. 5th Int. Coral Reef Symp, Tahiti 3:331–336

Randall JE (1987) Collecting reef fishes for aquaria. Human Impacts on coral reefs: facts and recommendations. B. Salvat ed., Antenne Museum EPHE, French Polynesia:29–39

Sadovy Y, Figuerola M (1992) The status of the red hind fishery in Puerto Rico and St. Thomas, as determined by yield-per-recruit analysis. Proc Gulf Carib Fish Inst 42:23–38

Smith CL (1973) Small rotenone stations: a tool for studying coral reef fish communities. Amer Mus Novitat 2512:pp 1–21

Taylor L, Nolan R (1978) Papers and comments on tropical reef fish. Working Paper No 34 August 1978 Sea Grant College Program, University of Hawaii

van Poollen HW, Obara AM (1984) Hawaii's marine aquarium fish industry profile. Studies on marine economics No 3 Ocean Resources Office Contribution No 14, pp 1–21

Wheaton JL (1989) The marine-life fishery for "live rock": biological and ecological assessment of the product and implications for harvest. Florida Marine Research Institute Flor Dept Nat Res, pp 1–18

Whitehead MJ, Gilmore E, Eager P, McMinnity P, Craik W, Macleod P (1986) Aquarium fishes and their collection in the Great Barrier Reef region. Great Barrier Reef Marine Park Authority Tech Mem GBRMPA-TM-13

Wood E (1985) Exploitation of coral reef fishes for the aquarium trade. Report to Marine Conservation Society UK, pp 1–129

Wood E (1992) Trade in tropical marine fish and invertebrates for aquaria: proposed guidelines and labelling scheme. A report for the Marine Conservation Society 36 pp